Christina River (Non-tidal)

Nutrient concentrations, flow rates, and mass loads (the product of the average daily flow rate and nutrient concentration) were examined for five stations of the non-tidal Christina River (Table 9). Time series graphs of flow rates and nutrient concentrations were first developed using all the data at each station. Time series graphs of nutrient concentrations and mass loads at low flow conditions (flow rates less than the 20th percentile annual flows) were also developed in order to detect any changes or trends over time. The time series graphs of nutrient concentrations and mass loads for each station are presented in Appendix H.

Table 9. Stations and data availability for the non-tidal Chrisitna River low flow analyses.

Stream Reach	Gage Number	Location	Data Available
East Branch Christina	DE-106191	Above Rt 273, Newark	Nutrients, Flow * (DE-DNREC)
West Branch Christina	DE-106161	At Rt. 2	Nutrients, Flow * (DE-DNREC)
Main Stem Christina	DE-106141 (01478000)	Cooch's Bridge	Nutrients, Flow (DE-DNREC)
Muddy Run – Becks Pond	DE-106121	Outflow of Becks Pond	Nutrients, Flow * (DE-DNREC)
Main Stem Christina	DE-106031	Outflow of Smalleys Pond – Head of Tide	Nutrients, Flow * (DE-DNREC)

* Note: Flow rates for these stations were estimated from flow rates measured at the Cooch's Bridge gage multiplied by the following factors based on drainage area and (0.15 - Above Rt 273; 0.25 – West Branch at Rt 2; 0.41 – Muddy Run/Becks Pond; 1.45 – Smalleys Pond). The value for Smalleys Pond also reflects the effects of water withdrawals based on information from UD-WRA.

Nutrient Concentrations and Mass Loads

As noted above, the time series graphs of nutrient concentrations and mass loads for the nontidal Christina River are shown in Appendix H. Mann-Whitney tests were run on the low flow data set to determine any statistically significant changes in concentrations or mass loads over time. The results of these analyses are summarized in Table 10 (statistically significant changes at the 0.05 level are indicated with "**"). All the stations are characterized by low to moderate nutrient concentrations under low flow conditions. Although several stations showed statistically significant reductions in NH_3-N and TP, these changes are likely due to the use of lower detection limits in the more recent samples. Data on the West Branch and Muddy Run/ Becks Pond were limited to data collected prior to 1993 and may not reflect existing conditions. A complete statistical summary of the data is presented in Appendx I.

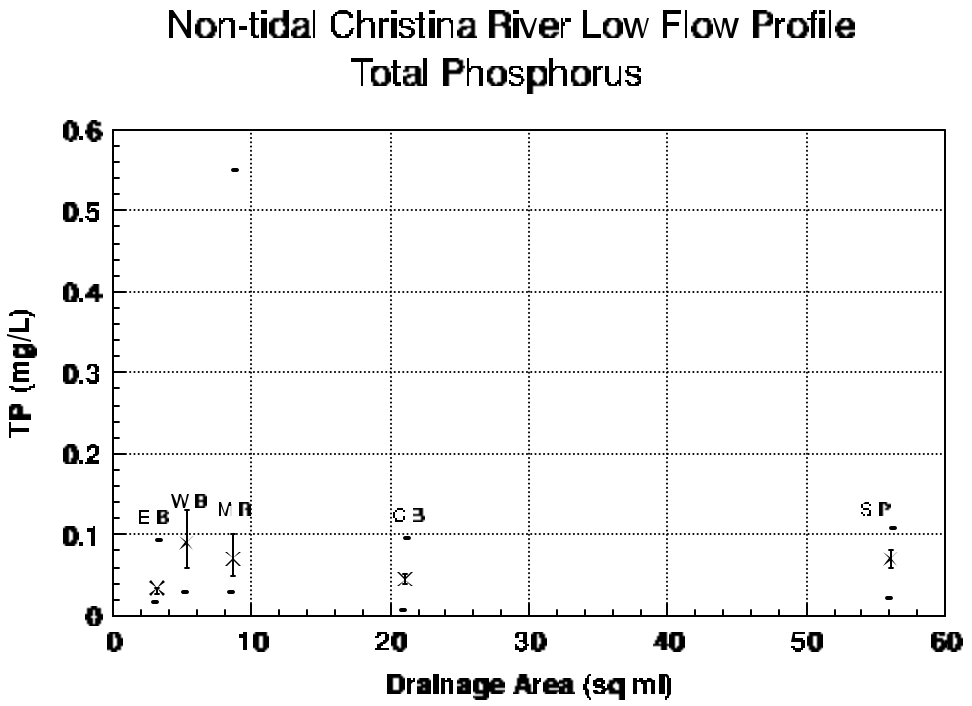
Table 10. Summary of median nutrient concentrations and mass loads at low flow conditions for the non-tidal Christina River. (** denotes a statistically significant change at the 0.05 level).

Station	Period	TP mg/L	TP Load lb/d	SOP mg/L	SOP Load lb/d	NH3-N mg/L	NH3-N Load lb/d	NO3-N mg/L	NO3-N Load lb/d
Above Rt 273	80-92 93-97	0.04 0.03	0.12 0.07	0.014 0.013	0.044 0.036	0.10 0.02	0.26 ** 0.07	1.70 1.75	5.4 6.4
West Branch Rt 2	80-93	0.09	0.4	N.A.	N.A.	0.10	0.5	1.95	9
Muddy Run/ Becks Pond	80-93	0.07	0.6	N.A.	N.A.	0.10	1.00	0.12	1
Cooch's Br.	80-92 93-97	0.09 ** 0.045	1.5 ** 0.92	N.A. 0.018	N.A. 0.35	0.10 ** 0.035	2.37 ** 0.73	1.12 1.35	24 31
Smalleys Dam	88-92 93-97	0.08 0.07	3.2 2.6	0.020 0.012	1.2 0.6	0.10 ** 0.082	4.4 2.6	0.70 0.67	25 25

Figures 33-36 show box plots of mass loads versus drainage area for the non-tidal Christina River. The nutrient concentrations tend to be in the low to moderate range throughout the non-tidal river. It should be noted that the data for the West Branch indicates significant variability in phosphorus and nitrate-nitrogen concentrations, and may not represent current conditions since the data only covers up to 1993. There are a number of point source discharges to this branch, which may or may not be represented by the available data. The data for Muddy Run/Becks Pond is only available up to 1993. The low nitrate concentrations at this station may not be representative of nitrogen concentrations upstream of the pond due to uptake of nitrate in the pond.

Summary of Findings for the Non-Tidal Christina River

Nutrient concentrations at the stations analyzed in the non-tidal Christina River are low to moderate and have remained fairly stable over time. Since several stations were located below ponds, it is possible that higher nutrient concentrations exist above the ponds. In addition, there is no recent data for some stations, which may be influenced by discharges located in Maryland.



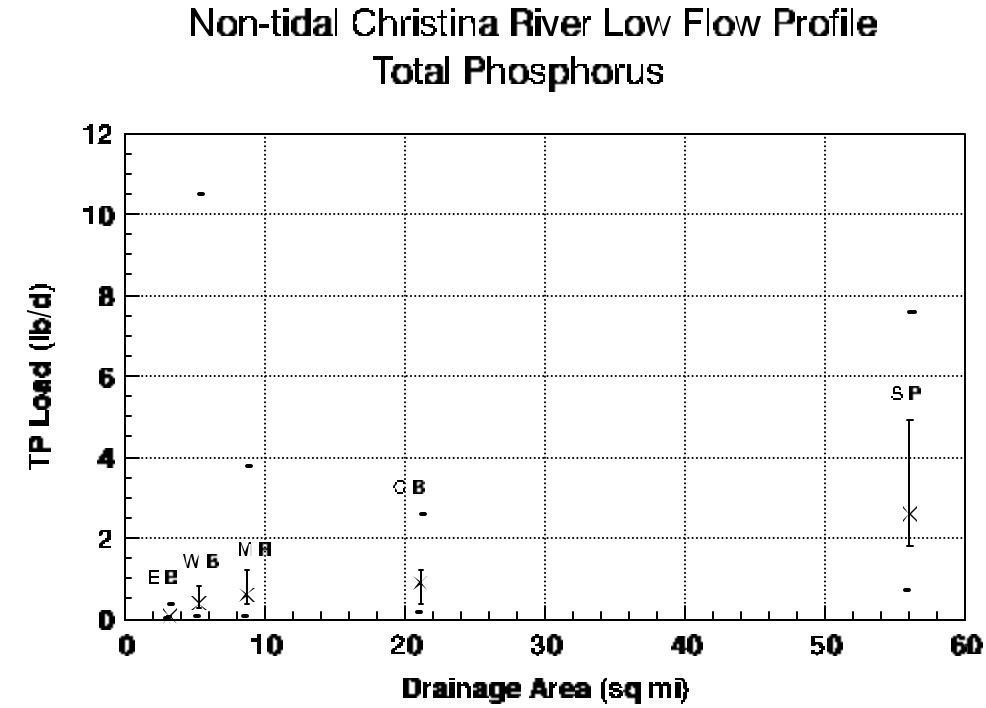
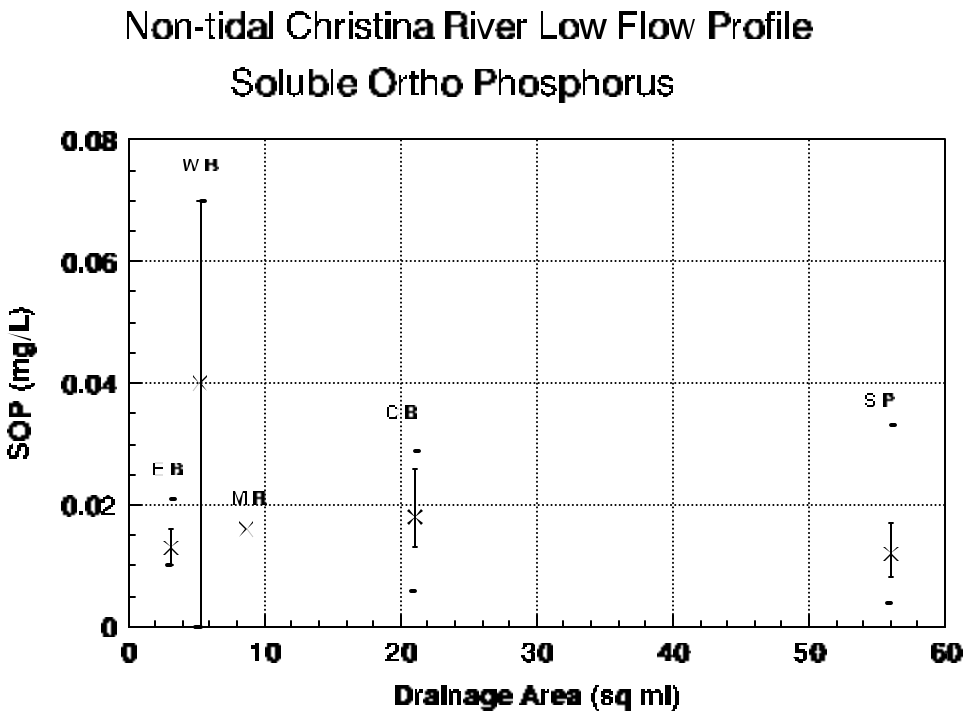


Figure 33a and b. Total phosphorus concentrations and mass loads at low flow conditions in the Chrisitna River as a function of drainage area (EB= East Branch, WB= West Branch, MR= Muddy Run, CB = Cooch's Bridge, SP = Smalley's Pond).



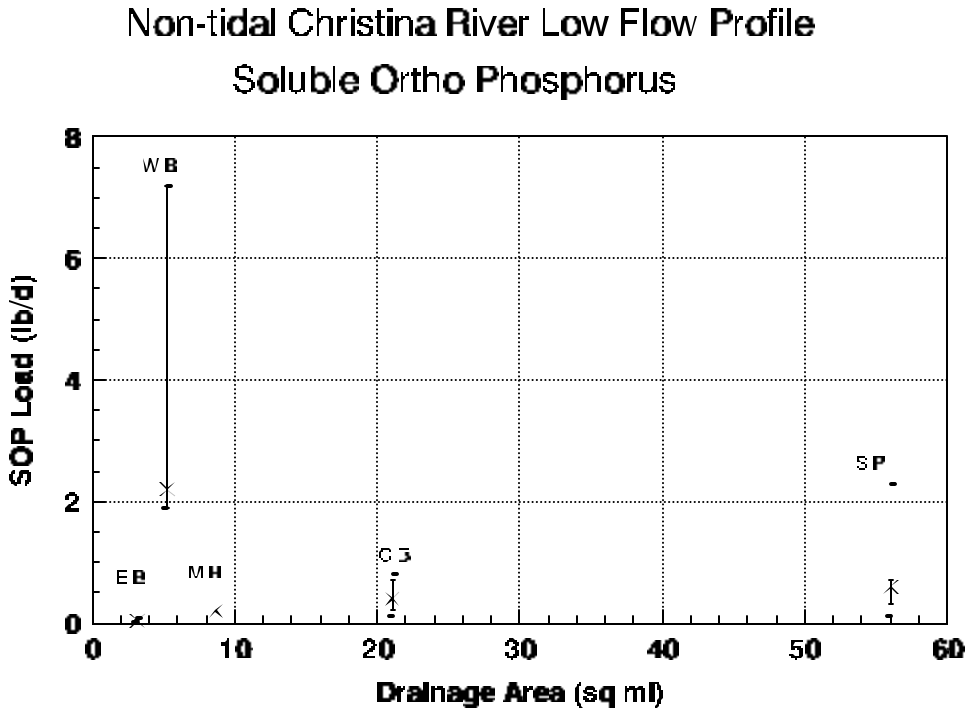
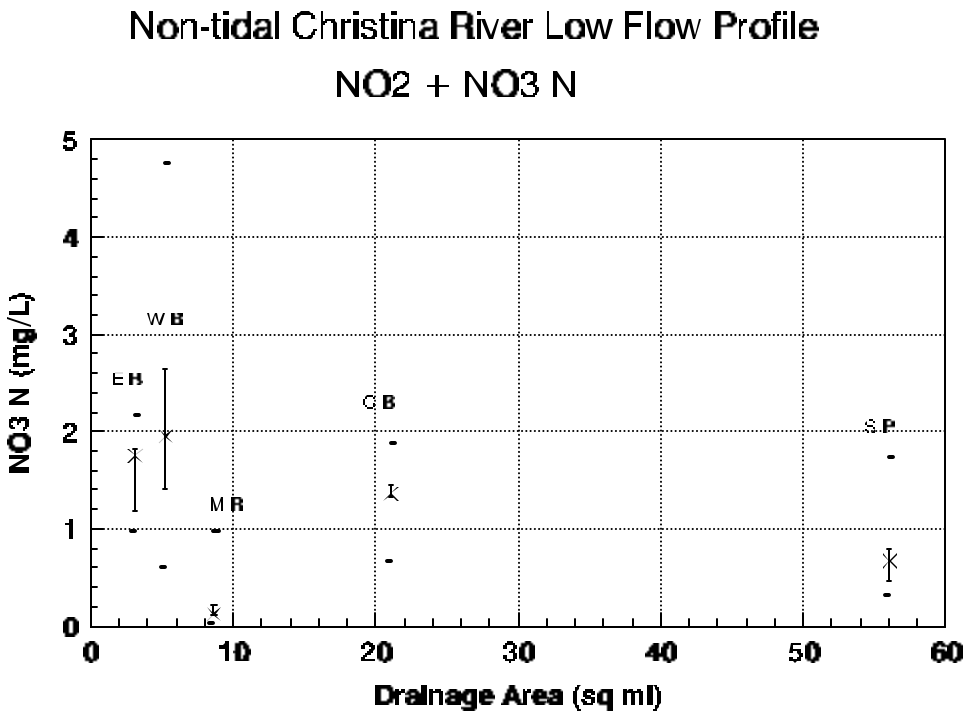


Figure 34a and b. Soluble ortho-phosphorus concentrations and mass loads at low flow conditions in the Chrisitna River as a function of drainage area (EB= East Branch, WB= West Branch, MR= Muddy Run, CB = Cooch's Bridge, SP = Smalley's Pond).



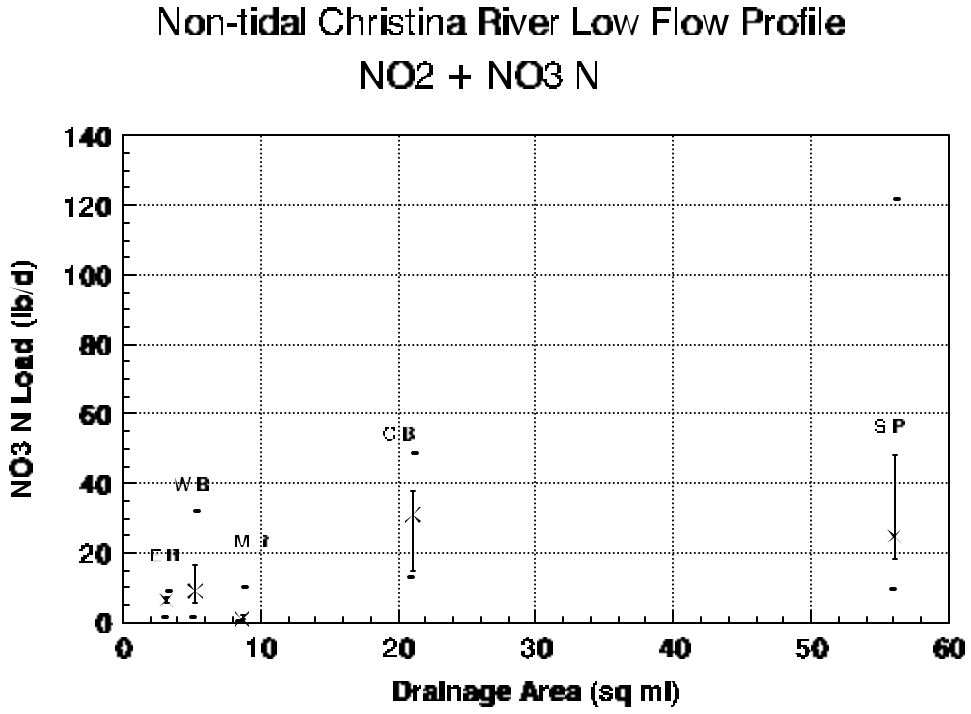


Figure 35a and b. Nitrate-nitrogen concentrations and mass loads at low flow conditions in the Chrisitna River as a function of drainage area (EB= East Branch, WB= West Branch, MR= Muddy Run, CB = Cooch's Bridge, SP = Smalley's Pond).

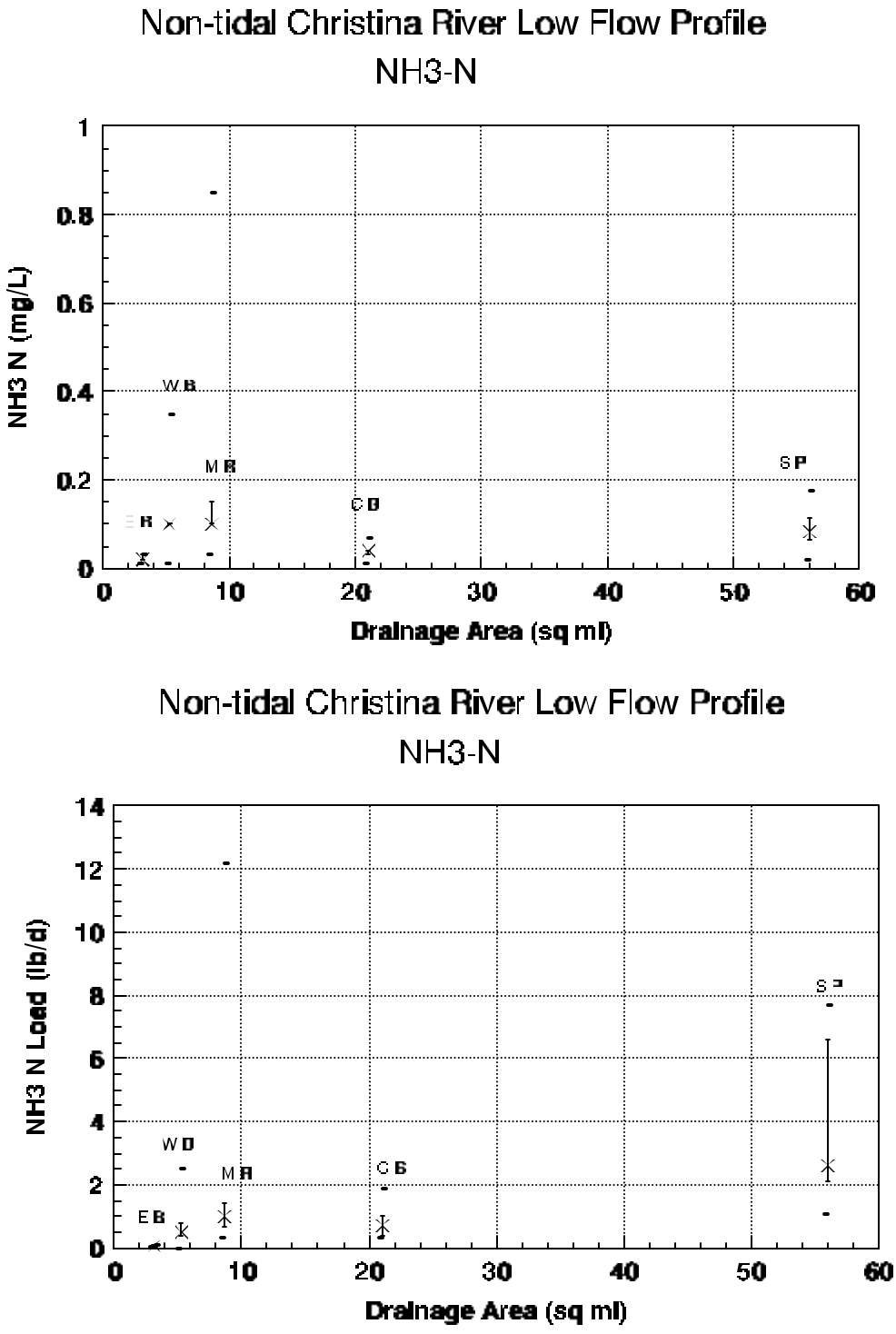


Figure 36a and b. Ammonia-nitrogen concentrations and mass loads at low flow conditions in the Chrisitna River as a function of drainage area (EB= East Branch, WB= West Branch, MR= Muddy Run, CB = Cooch's Bridge, SP = Smalley's Pond).

Tidal Christina River

Data on concentrations of nutrients, dissolved oxygen, organic carbon, BOD, and chlorophyll-a were analyzed for stations in the tidal Christina River at Newport (DE-106021) and at the Rt 13. Bridge (DE-106011) in Wilmington. The nutrient and dissolved oxygen data were analyzed from 1980 to present, whereas the organic carbon, BOD, and chlorophyll –a data were available starting in 1992. Time series graphs were generated for these stations and are presented in Appendix J. Two graphs were developed for each parameter: the first graph shows the data for May through October for all flow rates; the second graph shows the data for May through October during low flow conditions. The flow gage at Cooch's bridge was used to determine low flow conditions (< 20 % annual flow) for the Newport station, and the gage on the Brandywine River at Wilmington was used to determine low flow rates for the Rt 13. Bridge at Wilmington station.

In addition to the nutrient data, several data sets of continuous DO, temperature, specific conductance, and salinity were available for the tidal Christina River. These data were collected using hydrolabs by DE-DNREC during 1994-1995 at Newport and at the port of Wilmington. These data sets were examined to detect excursions of dissolved oxygen criteria in the tidal Christina.

Nutrient, Organic Carbon, and Chlorophyll-a Concentrations

Trends or changes in water quality were examined using Mann Whitney tests for each water quality parameter in order to compare median concentrations for the last 5 years of data (1993-1997) to the previous data (1980-1992). The median concentrations are summarized in Table 11, and a complete statistical summary is presented in Appendix K. There were no statistically significant changes over time in any of the water quality parameter. Comparison of the data between stations indicates that the Newport station has significantly higher organic carbon, chlorophyll-a, and pheophyton concentrations than the Wilmington (Rt 13) station, and the Wilmington station has significantly higher nitrate and soluble ortho-phosphorus concentrations. The Wilmington station is influenced by the water quality conditions in the Delaware River, which is typically high in nitrate concentrations. The Newport station reflects nutrient and organic loadings from the inland watersheds including the White Clay, Red Clay, non-tidal Christina River, and Churchmans Marsh, which has tidal exchange of water with the Christina River.

Table 11. Summary of median concentrations of nutrients, dissolved oxygen, organic carbon, and chlorophyll-a at low flow conditions for tidal Christina River. (** denotes a statistically significant change at a 0.05 level of significance).

Station	Period	TP mg/L	SOP mg/L	NH3 N mg/L	NO3 N mg/L	DO mg/L	TOC mg/L	DOC mg/L	BOD 20 mg/L	Chl-a ug/L	Pheo. ug/L
Newport	80-92	0.12	N.A.	0.10	0.73	6.65	N.A.	N.A.	N.A.	N.A.	N.A.
	93-97	0.14	0.01	0.04	0.49	6.05	10.0	7.0	4.30	37	102
Rt 13 Wilmington	80-92	0.13	N.A.	0.10	1.6	5.8	N.A.	N.A.	N.A.	N.A.	N.A.
	93-97	0.14	0.05	0.058	1.8	5.3	9.0	4.0	2.50	12	33

The chlorophyll-a and pheophyton concentrations at the Newport station are relatively high and are at levels that may be considered eutrophic. The pheophyton concentrations, which are used to indicate dead phytoplankton biomass, tend to be higher than the chlorophyll-a concentrations, which are used to indicate viable phytoplankton biomass. The build of high pheophyton and chlorophyll-a concentrations at the Newport station could be a result of growth and subsequent death of phytoplankton in the tidal estuary, the transport and accumulation of phytoplankton biomass from inland sources (such as non-tidal Christina River and Churchmans Marsh) or from the Delaware River. A review of chlorophyll-a concentrations in the Delaware River in the area of the Christina River indicates that chlorophyll-a concentrations are typically less than 10 ug/L (Hydroqual, 1998), which would tend to eliminate the Delaware as the source of phytoplankton to the tidal Christina. As discussed below, the high organic loads represented by the phytoplankton biomass in the Christina may be related to dissolved oxygen criteria excursions.

Continuous DO, Temperature, and Specific Conductance Data

Continuous DO, temperature, and specific conductance data were collected at the port of Wilmington for the following time periods: 9/2/94-9/9/94; 11/18/94-11/23/94; 4/18/95-4/25/95; 5/1/95-5/4/95; 6/19/95-6/23/95; 7/17/95-7/21/95; 8/28/95-9/1/95; and 9/12/95-9/15/95. Data at the Newport station were available for 9/2/94-9/9/94 and 11/18/94-11/23/94. Table 12 summarizes daily maximum, minimum, and average values for each survey for comparison to the water quality criteria. The DO criteria for the tidal Christina are a daily average DO of 5.5 mg/L and a minimum of 4.0 mg/L (DE

DNREC). The DRBC criterion is an average DO of 4.5 mg/L. The most severe criteria violations were observed during the July 1995 surveys when the average daily DO was less than 5.0 mg/L for 3 consecutive days and several DO observations were below 4.0 mg/L. DO values less than 4.0 mg/L were also recorded during the June, August, and September 1995 surveys, but these data points were single observations that appeared to be significantly different from the temporal trend in DO and may be unusual observations caused by problems with the monitor. The data from the later part of the April 1995 survey also has low DO values that were significantly different from the beginning of the survey and could also be caused by problems with the monitor.

Table 12. Summary of continuous DO, temperature, and specific conductance data from hydrolab surveys on the tidal Christina River.

Station and	DO (mg/L)			Temp (C)			Sp Cond (ms/cm)		
Date	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Newport									
9/3-8/94	12.1	8.2	7.1	24.0	23.2	20.4	0.4	0.3	0.3
11/19-22/94	11.6	9.9	8.5	12.3	11.3	8.6	1.7	0.7	0.0
Wilmington									
9/3-8/94	13.3	7.6	5.8	26.7	22.9	14.3	1.0	0.5	0.0
11/19-22/94	15.3	9.1	8.0	13.5	12.1	8.8	2.8	1.6	0.0
4/19-20/95	11.9	9.9	8.1	14.7	13.6	11.9	0.5	0.4	0.3
4/21-24/95	11.1	2.0	1.8	22.5	22.4	13.0	0.5	0.2	0.0
5/2-3/95	9.5	8.1	5.9	14.8	14.4	13.5	0.6	0.5	0.4
6/20-22/95	7.5	5.8	3.9	26.0	24.9	24.0	2.7	2.2	1.7
7/18-20/95	8.7	4.8	3.8	30.7	27.9	22.8	2.9	2.3	0.0
8/29-31/95	7.7	6.0	3.6	26.8	26.2	25.2	6.2	5.4	4.5
9/13-14/95	6.4	5.6	3.8	25.2	24.6	24.0	4.2	3.7	3.2

It is important to note the prevailing water quality conditions during the DO criteria excursions during the July 1995 surveys. The water temperature during the July survey was relatively high (maximum of 30.7 C and average daily of 27.9 C), which would impact DO concentrations due to decreased saturation values and by increased biochemical reaction rates which consume DO. Water quality data collected during July and August indicate that very high levels of pheophyton existed at the Newport (40-100 ug/L) and Rt. 13 Wilmington (over 30 ug/L) stations. These concentrations represent the presence of a high amount of organic matter from phytoplankton biomass in the estuary during this time, which could also represent a large DO sink.

In addition to the continuous DO data, the data obtained from the DNREC sampling program at Newport contains DO values below 5.0 mg/L during 1992 and 1996 which could indicate periods when the daily average or minimum DO criteria were violated. It appears that excursions of the daily average or minimum DO criteria occur from time to time in the tidal Christina, and these excursions may persist for an extended period of time under critical temperature and hydrologic conditions such as were observed during July 1995.

Summary of Findings for the Tidal Christina River

The nutrient concentrations in the tidal Christina River are primarily influenced by the tributary nutrient loads (the Brandywine, White Clay, Red Clay, and non-tidal Christina watershed including Churchmans Marsh) and the tidal Delaware River. Higher nitrate

and soluble ortho-phosphorus concentrations exist in the Wilmington area, which is likely related to the tidal exchange of water with the Delaware River. Moderate to high levels of chlorophyll-a and pheophyton exist during the summer, with higher levels occurring toward the inland end of the tidal river. Dissolved oxygen concentrations have dropped below the daily average and minimum criteria when water temperatures were relatively high (average temperatures of 28 C) and high levels of phytoplankton biomass (as measured by chlorophyll-a and pheophyton concentrations) existed. Based on the spatial distribution of the chlorophyll-a and pheophyton concentrations, it appears that high levels of phytoplankton biomass are not entering the Christina from the Delaware River. It is possible that the accumulation of phytoplankton biomass in the tidal Christina is due to the growth of phytoplankton within the estuary and/or the transport of phytoplankton from the inland tributaries including Churchmans Marsh.